first balloon, released at 2:46 p. m., rose at an average rate of 171 m/m, having been affected only slightly by convection. The second was released at 3:12 p. m., directly underneath a rather large cumulus cloud. A convectional gust caught the balloon as it left the ground, and from the end of the first to the third minute the ascensional rate was 422 m/m, or 264 per cent of the rate by formula. This gives an upward movement of the air around the balloon at a rate of 4.4 m/s. Such vertical gusts, usually much less marked, are the cause of "bumps" experienced on warm afternoons. If such a sustaining force were suddenly removed from an airplane the sensation would be that of a "hole in the air."

When convection is evident the air is also gusty, i. e., there is a rapid fluctuation in the horizontal or true wind velocity. In figure 5 it is seen that the velocity just off the ground drops from nearly 10 m/s. in the first ascent to less than 6 m/s. in the second.

Acknowledgment is due to Mr. W. R. Gregg for the use of the unpublished records of the Aerological Division on which the tables of average winds are based, and for valued suggestions and assistance rendered throughout
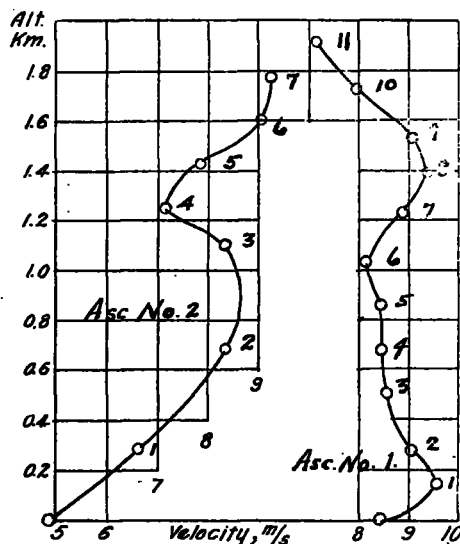

Fig. 5.—Time, altitude, velocity graph of pilot-balloon ascensions at Broken Arrow. Okla., June 25, 1920. No. 1 at 2:46 p. m. No. 2 at 3:12 p. m.

the preparation of this paper; also to the men of Broken Arrow station for the cooperation which enabled me to compute the data under conditions of very limited personnel.

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SURFACE WINDS AND LOWER CLOUDS.

By F. E. Hartwell, Meteorologist.

There is an unfortunate tendency among weather observers to record the lower clouds from the same direction as the surface wind. Indeed, in the writer's first lesson in taking a meteorological observation, when it came to the clouds, the entry was dictated to him: "3 stratus, SW., like the wind, *of course.*"[1]

Shortly thereafter, an intimate association with the West Indian hurricane in its own habitat indicated to him the importance of cloud drift in determination of direction of storm centers from the station, so that he has always been particularly careful to enter cloud directions from a careful sight, without reference to surface currents.

At the end of a year's work here in Burlington with pilot balloons, an examination of the record of flights made shows the fallacy of an assumption that the lower clouds, "of course," drift with the surface wind.

During the year, the actual direction of lower clouds was determined by means of balloon flights 186 times. Of these 186 only 28, or 15 per cent, were recorded the same direction as the surface wind. However, the directions in this work are recorded to sixteen points, while in ordinary meteorological observations they are recorded to only eight points. Therefore, those varying one-sixteenth either side of the surface direction must be included in determining the possible error. These bring the percentage of lower clouds with surface winds up to 38, less than four out of ten, quite a considerable error. Following the circle around, there were about one in four at a divergence of 45° from the surface wind, nearly one in three almost at right angles, 2 per cent at 135°, and 4 per cent nearly opposite.

This computation takes into consideration all directions. A segregation of the different directions is not particularly pertinent to the conclusion sought, but the deviation of the drift of lower clouds from surface wind direction varied somewhat with the surface direction, being greatest near east, and least at north. This variation would probably differ at different latitudes to such an extent that a detailed statement of it would be valueless.

The foregoing statements refer to occasions when a lower cloud direction was actually determined. The record was further examined with reference to the 500 and 1,000 meter levels, which include most lower clouds, and these results, with the foregoing, are included in the following table:

Percentage of direction of lower clouds and of drift at selected levels compared with surface wind direction.

Deviation from surface direction (degrees of azimuth).	Lower clouds (186 observations).	500-meter level (546 observations).	1,000-meter level (495 observations).
	Per cent.	*Per cent.*	*Per cent.*
0 (surface direction)	15	20	14
22½	23	37	24
45	26	20	22
67½	17	9	16
90	9	7	11
112½	4	2	5
135	2	2	3
157½	3	2	3
180	1	1	2

[1] It is hoped that such an instruction would be exceptional among officials in charge of Weather Bureau stations at present. We know that the observers at the majority of stations take pains to observe the direction of motion of the lower clouds.—Editor.

Reducing these values to the eight-point basis gives the following results:

Percentage of direction of lower clouds and of drift at selected levels compared with surface winds, deviation reduced to 8 points of the compass.

Deviation from surface direction.	Lower clouds.	500-meter level.	1,000-meter level.
	Per cent.	*Per cent.*	*Per cent.*
Practically with surface wind	38	57	38
Deviation of 45°	26	20	22
Practically at right angles	30	18	32
Deviation of 135°	2	2	3
Practically opposite	4	3	5

The observed lower clouds were taken by their form, and without regard to altitude, and varied from more than 1,000 meters to less than 500 meters above the earth's surface. It will be seen that the deviation increases decidedly with altitude, so that it can not be too strongly impressed upon observers begining Weather Bureau or other meteorological work that direction of lower clouds should not be assumed to be the same as the direction of the surface wind.

THE HIGHEST AERIAL SOUNDING.

In the *Meteorological Magazine* for November, 1920, No. 658, vol. 55, Mr. F. J. W. Whipple calls attention to the fact that the sounding-balloon record made at Pavia on December 7, 1911, heretofore accepted by many as the highest yet made, is in reality very questionable. Basing his figures upon the data given in a paper by Prof. Pericle Gamba, he finds that if the balloon *did* reach the great height claimed, viz, 35,030 meters, its mean rate of ascent during the latter part of its journey—from 27 to 35 kilometers altitude—was somewhat greater than 900 meters per minute, whereas its initial rate was about 235. At the highest point reached the indicated pressure was 4 mm. If this is correct, it means that the balloon's volume was nearly 200 times that at starting and the diameter 6 times. Mr. Whipple believes that the barograph was not working properly and, assuming a constant ascensional rate, finds that the altitude reached was about 19 kilometers. Although the original height given, 35,030 meters, does appear very questionable, it is difficult to accept this recomputed value, since it is based entirely upon an assumed constant ascensional rate of the balloon. It is true that small pilot balloons rise at very nearly a constant rate, but it is not true that the larger balloons, from which instruments are suspended, do so. The sounding-balloon ascensions made in this country show, in practically all cases, an increasing rate of ascent with increasing altitude. In 20 ascensions at Fort Omaha, Nebr., and Huron, S. Dak.,

the mean rate increased from 180 meters per minute near the surface to 300 at 15 kilometers. (See BULLETIN MOUNT WEATHER OBSERVATORY, Washington, 1911, 4: 187.) In 7 ascensions at Avalon, Calif., the mean rate increased from 185 meters per minute near the surface to 295 at 18 kilometers. (See MONTHLY WEATHER REVIEW, Washington, 1914, 42: 411.) Objection may be raised to these records as reliable evidence, since the heights were themselves computed from the pressure records. This is true in the cases cited, but in 1914 several balloons were followed by 2 theodolites at Fort Omaha, Nebr. (See MONTHLY WEATHER REVIEW, Washington, 1916, 44: 247–264.) A base line 5,088 meters in length was used. The results indicated close agreement between altitudes determined from triangulation and those from the barograph. Using only those ascensions in which the balloons were followed by 2 theodolites, we find that the mean rate of ascent increased from 150 meters per minute near the surface to 240 at 17 kilometers. The increase is fairly constant at all altitudes below 15 to 18 kilometers and is practically the same in the individual ascensions. It seems certain, therefore, that the height reached by the Pavia balloon was considerably greater than that computed on the basis of a constant rate of ascent. It seems also quite certain that that height was considerably less than 35 kilometers.

Mr. Whipple inquires what sounding is the highest on record, if the Pavia record is to be deprived of that distinction. So far as known, the next highest observation published is that made at Avalon, Calif., on July 30, 1913. As computed from the barograph trace, an altitude of 32,640 meters was reached. The pressure was 7.4 millimeters. The rate of ascent was about 100 meters per minute near the surface, 275 at 16 kilometers, and 520 at the highest altitudes.

The next highest record in this country was that obtained at Fort Omaha, Nebr., July 9, 1914. Unfortunately, the meteorograph clock stopped when an altitude of 17,560 meters had been reached. This altitude, by the way, was determined by triangulation as well as from the pressure trace. The clock started again when the balloon burst, and fortunately the time of bursting was ascertained, the balloon still being followed by one of the theodolites. Thus it is possible to determine the mean rate of ascent at the highest altitudes, if we can assume that the indicated pressure at the time of bursting of the balloon was correct. That pressure was 8.6 millimeters, giving an altitude of 31,600 meters. The rate of ascent was 115 meters per minute near the surface, 230 at 15 to 17 kilometers, and 395 at the highest altitudes.

One other sounding above 30 kilometers was made on September 1, 1910, at Huron, S. Dak. The indicated pressure was 9.8 millimeters, and the computed altitude, 30,490 meters. The rate of ascent was 150 meters per minute near the surface, 330 at 15 to 18 kilometers altitude, and 367 at the highest levels.—*W. R. Gregg.*